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UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF OHIO
WESTERN DIVISION

- - -

UNITED STATES OF AMERICA, : CASE NO. 1:18-cr-0043
:
Plaintiff, :
vs. : TRIAL EXCERPT
:
YANJUN XU, also known as XU : 28th of OCTOBER, 2021
YANJUN, also known as QU HUI, : 2:32 P.M.
also known as ZHANG HUI, :
:
Defendant. :

- - -

TRANSCRIPT OF PROCEEDINGS
BEFORE THE HONORABLE TIMOTHY S. BLACK, JUDGE

- - -

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9 Yanjun Xu, Defendant

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10 Courtroom Deputy: Bill Miller

11 Stenographer: Mary Schweinhagen, RPR, RMR, RDR, CRR
12 United States District Court
13 200 West Second Street, Room 910
14 Dayton, Ohio 45402

14 Proceedings reported by mechanical stenography,
15 transcript produced by computer.

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1 P-R-O-C-E-E-D-I-N-G-S

1:55 P.M.

2 (Proceedings reported but not transcribed.)

02:32:21 3 THE COURT: The government's going to call another
02:32:22 4 witness at this time. Who does the government call,
02:32:25 5 Ms. Gladfelter?

02:32:26 6 MS. GLATFELTER: Thank you, Your Honor. We call
02:32:27 7 Nick Kray to the stand.

02:32:29 8 THE COURT: If that gentleman would be willing to
02:32:32 9 approach. I am going to put you up on the witness stand. And
02:32:38 10 if you'd be willing to pause where you are, I am going to ask
02:32:42 11 you to take the oath to tell the truth.

02:32:44 12 Our right hands are raised. Do you solemnly swear or
02:32:47 13 affirm that your testimony today will be the truth, subject to
02:32:50 14 the penalty of perjury?

02:32:51 15 THE WITNESS: I do.

02:32:52 16 THE COURT: Very well. Climb up and get you
02:32:56 17 acclimated.

02:33:00 18 THE WITNESS: Is it okay to take this off
02:33:01 19 (indicating)?

02:33:01 20 THE COURT: If you wish to take your mask off, you
02:33:04 21 may.

02:33:04 22 THE WITNESS: Thank you.

02:33:06 23 THE COURT: We'll need you up close to that fancy
02:33:09 24 federal microphone. Exhibits may come up on the screen or in
02:33:15 25 paper in front of you.

KRAY - DIRECT (Glatfelter)

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02:33:16 1 The attorney for the government has a chance to begin
02:33:18 2 with questions of you.

02:33:20 3 Ms. Gladfelter.

02:33:21 4 MS. GLATFELTER: Thank you, Your Honor.

02:33:23 5 **DIRECT EXAMINATION**

02:33:23 6 BY MS. GLATFELTER:

02:33:25 7 Q. Mr. Kray, can you state and spell your name for the
02:33:27 8 record?

02:33:27 9 A. Yes. Nicholas Kray. N-I-C-K K-R-A-Y.

02:33:33 10 Q. And, Mr. Kray, are you currently employed?

02:33:36 11 A. Yes.

02:33:36 12 Q. Where?

02:33:38 13 A. General Electric Aircraft Engines.

02:33:41 14 Q. What does -- does it also go by GE Aviation?

02:33:43 15 A. Yes.

02:33:44 16 Q. And what does GE Aviation do?

02:33:46 17 A. We, well, design and manufacture commercial and
02:33:50 18 military aircraft engines.

02:33:52 19 Q. Who does GE Aviation sell its engines to?

02:33:56 20 A. So we're a global company. We sell engines basically
02:34:02 21 to any airline globally across the -- across the world.

02:34:07 22 Q. How long have you worked for GE Aviation?

02:34:09 23 A. Over 33 years.

02:34:13 24 Q. And what's your current position there?

02:34:15 25 A. I'm a chief consulting engineer for polymeric

KRAY - DIRECT (Glatfelter)

6

02:34:20 1 composites.

02:34:22 2 Q. I'm sorry. You said for what?

02:34:24 3 A. Polymeric composites.

02:34:27 4 Q. Polymeric composites?

02:34:31 5 A. Yes.

02:34:31 6 Q. Can you explain what you do, like, every day for your
02:34:35 7 position? What a day in the life of Nick Kray is?

02:34:39 8 A. Okay. So I work in the chief engineer's office, and
02:34:42 9 it's -- the chief engineer's office is essentially an
02:34:45 10 independent engineering division within aviation. We have
02:34:50 11 kind of three main goals. First one is safety. I mean, in
02:34:55 12 aviation safety is obviously number one for everything that
02:34:59 13 we work on.

02:35:00 14 Number two is to make sure that all of our designs are
02:35:07 15 evaluated with design rigor to make sure that when we
02:35:10 16 release either a new product to the field or we fix a field
02:35:19 17 product that's existing, we do as much rigor as possible to
02:35:23 18 make sure that that's a good fix or good product.

02:35:26 19 And number three is to actually mentor our younger
02:35:29 20 engineers in a technical track to make sure we build a
02:35:35 21 strong technical base for our next generation of engineers.

02:35:37 22 Q. And you said that you work in the area of polymeric
02:35:42 23 composites? Did I pronounce that right?

02:35:43 24 A. Yes.

02:35:43 25 Q. I want to come back in that area in a moment, but I want

KRAY - DIRECT (Glatfelter)

7

02:35:46 1 to understand more what a chief consultant engineer does. Can
02:35:50 2 you describe that to the jury?

02:35:51 3 **A.** Sure. So I get involved in all different type of
02:35:55 4 issues at Aviation, whether it's a new product introduction,
02:35:57 5 a new design, so to speak. We typically have to make sure
02:36:01 6 the design rigor and the way we approach the design is
02:36:05 7 adequate, that we result in a safe design; or if we have a
02:36:09 8 field problem, to make sure that we pull the right team
02:36:12 9 together to work on that field problem to make sure we
02:36:15 10 address it and fix it for our customers.

02:36:18 11 **Q.** How long have you been the chief consultant engineer?

02:36:22 12 **A.** It's been a little bit over a year now.

02:36:24 13 **Q.** And what did you do before that at GE Aviation?

02:36:28 14 **A.** Before that, I was in other technical positions of
02:36:33 15 consulting engineer and principal engineer, again in
02:36:37 16 polymeric composites. I worked on MPI design and sustaining
02:36:42 17 programs to support both of those.

02:36:44 18 **Q.** And your area of focus has been polymeric composites
02:36:50 19 through those different positions?

02:36:52 20 **A.** Polymeric composites has been my expertise for probably
02:36:56 21 25 years now.

02:36:58 22 **Q.** What kind of training and experience has prepared you for
02:37:02 23 your current position.

02:37:04 24 **A.** So certainly -- certainly school, you know, the
02:37:08 25 baseline college education. I have a master's and a

KRAY - DIRECT (Glatfelter)

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02:37:10 1 Bachelor's of Science in mechanical engineering, both in the
02:37:16 2 University of Cincinnati.

02:37:17 3 We have in-house training. General Electric offers
02:37:21 4 their employees a very rigorous training program. It's on a
02:37:25 5 selected basis. You can take these courses at your -- at
02:37:28 6 your leisure. And then obviously trying to keep our
02:37:33 7 transfer of knowledge between senior engineers and younger
02:37:38 8 engineers, you always work within a team to make sure that
02:37:41 9 you, again, gain the knowledge from the more senior people
02:37:44 10 and kind of build upon that.

02:37:47 11 Q. Thank you. So you said you have a bachelor's degree?

02:37:50 12 A. Correct.

02:37:50 13 Q. And what is that in?

02:37:51 14 A. Mechanical engineering.

02:37:52 15 Q. And where did you get that from?

02:37:54 16 A. From the University of Cincinnati.

02:37:56 17 Q. Thank you. During your career at GE Aviation, you said
02:38:00 18 you focused on polymeric composites for how many years?

02:38:04 19 A. About 25.

02:38:05 20 Q. Can you explain to the jury what a composite is? When
02:38:13 21 you use that term, what you mean?

02:38:14 22 A. Okay. So composite is a very broad term. Think about
02:38:17 23 it as taking two different materials and mixing them
02:38:18 24 together, but when the resulting product of those materials
02:38:21 25 is still separate.

KRAY - DIRECT (Glatfelter)

9

02:38:23 1 So -- so an easiest way to say, for example, when you
02:38:27 2 put a cast on your arm. You mix fibers with a plaster of
02:38:35 3 paris. You mix it up and you wrap it on your broken arm or
02:38:38 4 leg, and that cures, and it cures as a hard substance. That
02:38:41 5 essentially is a composite in a very broad sense.

02:38:45 6 THE COURT: Can I interrupt and ask you to bring the
02:38:48 7 microphone closer?

02:38:49 8 THE WITNESS: Sure.

02:38:50 9 BY MS. GLATFELTER:

02:38:50 10 Q. So you were using the analogy of a cast?

02:38:52 11 A. Correct.

02:38:53 12 Q. Okay. I just want to make sure everyone could hear you.
02:38:56 13 If you could repeat that last answer for us. You were trying
02:39:00 14 to give us an analogy of what a composite is. If you could
02:39:04 15 repeat that while you are closer to the microphone so everyone
02:39:07 16 can hear you.

02:39:07 17 A. Yeah, sure. So composite is a substance that is
02:39:10 18 typically fibrous and a binder material. So as a cast, you
02:39:16 19 typically put a fibrous, a cloth material, you dip it in
02:39:20 20 plaster of paris, wrap it on your arm or a leg, and then it
02:39:26 21 cures or hardens, and the resulting structure is essentially
02:39:32 22 a composite.

02:39:33 23 Q. Now, is there a particular area that you have been
02:39:36 24 involved in during your career, a certain application of those
02:39:39 25 composites at GE Aviation?

KRAY - DIRECT (Glatfelter)

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02:39:40 1 A. Yes. My main involvement over the last 25 years has
02:39:44 2 been on composite fan blades and fan cases.

02:39:47 3 Q. What's the function of a fan blade and a fan encasement?

02:39:54 4 A. So a blade -- a blade in a triple fan engine
02:39:59 5 essentially pumps the air. That's the whole purpose of it.
02:40:02 6 And pumping of the air gives the aircraft thrust. So it's
02:40:06 7 to pump the air.

02:40:08 8 The containment case is to make sure that if we -- if
02:40:12 9 the blade releases inadvertently from the retaining
02:40:17 10 structure, it is still contained, does not hit the fuselage
02:40:20 11 of the aircraft.

02:40:21 12 MS. GLATFELTER: Okay. And if we can show the jury
02:40:26 13 and the witness Exhibit 78, which is already admitted into
02:40:29 14 evidence?

02:40:29 15 THE COURT: Yes, we can publish it.

02:40:31 16 MS. GLATFELTER: Thank you.

02:40:37 17 THE COURT: So could you move your binder to your
02:40:40 18 left, sir. Way over. Now, will you pull the microphone in
02:40:46 19 front of your mouth and speak to the jury and turn your head.
02:40:51 20 It's hard.

02:40:51 21 THE WITNESS: Okay.

02:40:52 22 THE COURT: You're doing fine.

02:40:53 23 Go ahead. Sorry.

02:40:55 24 MS. GLATFELTER: Thank you, Your Honor.

02:40:58 25 BY MS. GLATFELTER:

KRAY - DIRECT (Glatfelter)

11

02:40:59 1 Q. All right. Does this graphically or illustrate the
02:41:03 2 concepts you were mentioning before about the propulsion of
02:41:06 3 the fan blades and the function of the fan blades and
02:41:11 4 encasement?

02:41:12 5 A. Okay. You want me to go through this --

02:41:14 6 Q. Yes.

02:41:14 7 A. -- figure here.

02:41:15 8 Q. Will this help you explain?

02:41:17 9 A. Yes, certainly it will help. I think it will help the
02:41:19 10 jury understand as well.

02:41:20 11 Q. And I think if you touch your screen, I think we can --
02:41:23 12 you can point to different parts as you're speaking. There
02:41:28 13 you go.

02:41:29 14 A. Okay. So to give a little bit of Jet Engine 101 so
02:41:36 15 everybody can understand it.

02:41:36 16 So when you look at an aircraft, you obviously have the
02:41:39 17 aircraft, but the engines are what typically sit underneath
02:41:43 18 the wing. And typically they look like a couple big tubes,
02:41:46 19 right? I mean, all you see are the white tube coverings on
02:41:50 20 that jet engine.

02:41:52 21 If you took that cell covering off, you would see a
02:41:56 22 structure that's similar to this, all right? This is the
02:41:58 23 carcass of a jet engine. It's a cut-away view, so you can
02:42:03 24 see some of the internals in a jet engine.

02:42:06 25 The jet engine's made up of a couple of different

KRAY - DIRECT (Glatfelter)

12

02:42:09 1 modules here. The fan module, which is this guy right here
02:42:15 2 (indicating), is the main pumping for air. And the big
02:42:18 3 purpose for that is to get as much air through the --
02:42:22 4 through the engine as possible. As it pumps air, it pushes
02:42:25 5 the aircraft forward.

02:42:27 6 The thing that makes the aircraft fly is forward
02:42:31 7 velocity from the engine. The wings make it lift. And
02:42:35 8 that's how you get flight. Okay? So the engine's doing all
02:42:37 9 the pushing.

02:42:38 10 So the fan module is up here (indicating). Then you
02:42:41 11 have a compressor module here (indicating) which compresses
02:42:46 12 more air, so the air kind of comes into the engine. We
02:42:49 13 compress it very, very tightly, okay. Pressure ratio gets
02:42:53 14 very compact. Right here (indicating) we add fuel into that
02:42:57 15 compressed air. The fuel lights off, expands the air even
02:43:02 16 more, and it comes out the back of the engine, okay.

02:43:06 17 Now, a couple things happen. When it expands, it goes
02:43:09 18 through the turbine blades here (indicating). The turbine
02:43:13 19 blades are hooked to the compressor blades so they spin at
02:43:17 20 the same time. So I'm feeding energy to continue my
02:43:20 21 pumping. So I add fuel and I pump it, and I continue to
02:43:24 22 pump fuel, and then as it exits the aircraft it goes through
02:43:31 23 the pumper feed back here (indicating). And it drives the
02:43:34 24 fan blades and pumps the majority of the air to get the
02:43:38 25 thrust to the engine. That whole system basically makes as

KRAY - DIRECT (Glatfelter)

13

02:43:41 1 much forward thrust on the aircraft as possible.

02:43:43 2 Q. Mr. Kray, we also -- or you mentioned before the fan
02:43:46 3 encasement system?

02:43:47 4 A. Um-hmm.

02:43:48 5 Q. Do you see that on this illustration?

02:43:50 6 A. Yes.

02:43:51 7 Q. Okay.

02:43:51 8 A. The containment system is here (indicating), cross-
02:43:54 9 section view. It goes all the way around the fan blades.

02:44:00 10 The cut-away view, you can't obviously see all of it, but it
02:44:04 11 encompasses the fan blades.

02:44:06 12 Q. All right. And what are -- if the fans help propel and
02:44:08 13 push the air to the compressor, what's the function of the
02:44:10 14 encasement system?

02:44:11 15 A. So one of the -- one of the requirements from the
02:44:18 16 Federal Aviation Administration for safety, again, is to
02:44:22 17 design a system such that if one of these blades breaks,
02:44:27 18 okay, and releases from the spinning, this holds it. It has
02:44:34 19 to be contained within this containment structure so it
02:44:37 20 doesn't hit the aircraft and obviously damage passengers.

02:44:43 21 It doesn't happen that often. Fan blade releases do
02:44:48 22 very seldom happen. We have had a case -- and it's been in
02:44:52 23 the newspaper just, I guess it was in February, of one of
02:44:54 24 our competitors that lost a fan blade, did a lot of damage.
02:44:58 25 The inlet ended up on the ground and in somebody's front

KRAY - DIRECT (Glatfelter)

14

02:45:01 1 yard in Texas.

02:45:02 2 So it does happen. We have to design to make it as
02:45:05 3 safe as possible.

02:45:06 4 **Q.** And in order to have an engine certified, do you have to
02:45:12 5 test the capability of your fan encasement?

02:45:16 6 **A.** Yes. The Federal Aviation Administration requires a
02:45:19 7 full engine blade-out test for certification. We have to
02:45:22 8 take a complete engine, intentionally release a fan blade,
02:45:26 9 and show containment in a safely -- a safe shutdown of that
02:45:29 10 engine if that indeed happens.

02:45:32 11 **Q.** Now, have you been involved in the development of GE's
02:45:35 12 fan blade and containment system over the course of your
02:45:38 13 career?

02:45:41 14 **A.** Yes.

02:45:41 15 **Q.** And in what roles?

02:45:42 16 **A.** So my first encounter with composites, polymeric
02:45:50 17 composites, was on the GE90-115B fan blade design. I was on
02:45:54 18 the design team for that. And that's -- our GE90 engine
02:45:58 19 goes on the 777 aircraft. That was a new product
02:46:02 20 introduction. It was a brand new design. I saw that
02:46:05 21 through design and certification, which included the
02:46:08 22 testing, including fan blade-out.

02:46:11 23 Then I was a team lead for our GENx engine family. At
02:46:17 24 GENx, we have a 1B GENx engine, which goes on a 787
02:46:24 25 aircraft; and we have a GENx-2B family, very similar, which

KRAY - DIRECT (Glatfelter)

15

02:46:28 1 goes on the 747-800 aircraft.

02:46:31 2 And then just recently, as a consulting engineer or
02:46:35 3 chief consulting engineer, of involvement on our GE9X
02:46:39 4 engine, which is our latest offering on a 777X, which is yet
02:46:44 5 to be certified by Boeing. So it's a certified engine but
02:46:49 6 not a certified aircraft yet.

02:46:50 7 Q. And what part of the engine have you worked on?

02:46:54 8 A. Typically the blades and the casement the majority of
02:47:00 9 the time. Obviously, we have other composite sundry parts
02:47:05 10 in the engine, but the majority of it has been the cases and
02:47:09 11 the blades.

02:47:09 12 Q. And have you been involved in the design process for
02:47:13 13 using a composite material for GE fan blades?

02:47:17 14 A. Yes.

02:47:17 15 Q. And GE containment systems?

02:47:20 16 A. Yes.

02:47:20 17 Q. Okay. When did GE start using composite material for its
02:47:24 18 fan blades?

02:47:25 19 A. Our first fan blade design was started probably 1989,
02:47:36 20 maybe early '90. And that was -- it was certainly developed
02:47:42 21 before that as far as a subcomponent testing, et cetera, but
02:47:46 22 the final product was certified in 1995 on our GE94B, which
02:47:51 23 was the first engine that we put on a 777 before the 115B.

02:47:57 24 Q. And that engine had composite fan blades?

02:47:59 25 A. Correct.

KRAY - DIRECT (Glatfelter)

16

02:47:59 1 Q. Does GE Aviation have particular expertise in this area,
02:48:05 2 composite fan blades?

02:48:06 3 A. I think we're probably the world leader in composite
02:48:11 4 fan blades. Actually, nobody else has composite fan blades
02:48:16 5 certified in production other than General Electric.

02:48:21 6 Q. Is GE Aviation the only company in the world that has the
02:48:25 7 combination of the composite fan blade and containment system?

02:48:28 8 A. That is correct.

02:48:30 9 Q. Does GE derive a competitive advantage from using the
02:48:35 10 composite fan blade with the composite encasement system?

02:48:39 11 A. Certainly. It is one of our, I would say, biggest
02:48:45 12 advantages in the commercial airspace, is that combination.

02:48:48 13 Q. Why -- what is unique about being able to use a composite
02:48:52 14 material in a fan blade? How is that advantageous?

02:48:56 15 A. Okay, so to give a little bit of background. So
02:49:01 16 typically aircraft engines up until our introduction of
02:49:04 17 composites had metal blades. And the material of choice has
02:49:08 18 typically been titanium. That's been the industry standard
02:49:11 19 ever since, you know, the 1940s.

02:49:14 20 The problem with that is these engines run at very high
02:49:20 21 RPM. It spins very fast. And imagine yourself pulled in
02:49:25 22 onto a rock on a rope and spinning it around, okay. And you
02:49:28 23 got to hold onto that rope pretty, pretty hard, right? If I
02:49:33 24 put a bigger rock on that rope, it's going to get even
02:49:36 25 harder to -- you spin at the same RPM, it's going to get

KRAY - DIRECT (Glatfelter)

17

02:49:40 1 even harder to hold; am I right?

02:49:40 2 When you get to the size of these engines, which are
02:49:44 3 very large -- our GEnx9 -- our GE9X is, you know, 13 feet in
02:49:51 4 diameter. So the blades are very, very large. To hold onto
02:49:56 5 those would be almost impossible -- well, it would be
02:49:58 6 impossible if they were metallic. So we have to look at
02:50:01 7 lighter alternatives.

02:50:02 8 Composite material is about a third of the density of
02:50:06 9 titanium. All right. So I'd certainly have an advantage if
02:50:08 10 I can make it a lighter blade, still pump the air and get
02:50:12 11 the same performance, and yet be able to hold onto that
02:50:15 12 blade as it spins very fast.

02:50:17 13 Now, our competitors have gone to hollow titanium as an
02:50:22 14 alternate. All right. Hollow titanium has a lot of
02:50:26 15 disadvantages in that it has a lot of stress risers internal
02:50:30 16 to the blade because it's got hollow cavities. And when you
02:50:34 17 machine out something with very tight radiuses, you get very
02:50:38 18 high stress concentrations.

02:50:40 19 Our composite blades don't have that. They are
02:50:43 20 monolithic. They are 100 percent composite through. And
02:50:46 21 they are, again, a third of the density. So we have that
02:50:49 22 advantage, from a design perspective.

02:50:51 23 **Q.** Let me ask you a few questions about that. So you
02:50:54 24 mentioned stress risers?

02:50:55 25 **A.** Yes.

KRAY - DIRECT (Glatfelter)

18

02:50:55 1 Q. Do I have that term right? What did you mean by that?

02:51:00 2 A. So I guess I'll go back to the recent example I talked
02:51:02 3 about earlier. One of our competitors had a fan blade
02:51:06 4 failure in February. I think it was February of this year.
02:51:08 5 That resulted from stress concentration internal in the
02:51:11 6 blade because it was a hollow metallic blade.

02:51:13 7 The stress concentrations basically have a high stress
02:51:19 8 in a certain area of the blade. And as that stress either
02:51:24 9 works itself from an LCF perspective -- you know, think
02:51:27 10 about a paper clip. I bend a paper clip back and forth,
02:51:31 11 back and forth, eventually, it's going to break.

02:51:34 12 So what happens is when you have a stress
02:51:37 13 concentration, as I cycle that blade, on every flight it
02:51:40 14 takes off, it takes -- comes down. Every flight it gets
02:51:42 15 more and more cycles. Eventually, if I have a stress
02:51:45 16 concentration it will start to propagate a crack in that
02:51:48 17 local area, which can then lead to a blade separation.

02:51:52 18 Q. So when you talk about greater durability, that's what
02:51:55 19 you're talking to in terms of the composite fan blades?

02:51:57 20 A. Yes. Composites inherently have much better durability
02:52:01 21 than metallics. On a back-to-back basis, the fatigue
02:52:06 22 capability of composites is superior to any -- any
02:52:09 23 metallics.

02:52:10 24 Q. You mentioned before that they are lighter than hollow
02:52:14 25 titanium or metallics. What is the benefit of having a weight

KRAY - DIRECT (Glatfelter)

19

02:52:20 1 reduction for your engines?

02:52:21 2 **A.** So, again, you know, we build engines for our
02:52:24 3 customers. Our customers want a light -- as weight-
02:52:28 4 efficient design as possible. And we try to provide that.
02:52:31 5 Certainly safety first, but then give it a light design.

02:52:37 6 The more I can take weight out of the engine -- because
02:52:39 7 every time the aircraft takes off, that weight goes with the
02:52:42 8 engine, right? I lift it up each time. The lighter I can
02:52:47 9 make it means I can either put more passengers on the
02:52:51 10 aircraft or I can put more seats in the aircraft; I can
02:52:54 11 either go the same amount of seats, I can go farther
02:52:57 12 distance. I can fly from, you know, let's say the United
02:53:00 13 States to India, for example, versus having to stop in
02:53:02 14 Europe. So I can go farther if I have a lighter design.

02:53:09 15 **Q.** Thank you, Mr. Kray. You've been working on this
02:53:12 16 technology for a long time. How long has it taken GE Aviation
02:53:16 17 to develop the composite fan blade technology?

02:53:19 18 I'm sorry. Go ahead and take a drink, please.

02:53:29 19 **A.** A typical NPI introduction of a new material, like
02:53:34 20 composites -- and I'll go by our experience -- it took
02:53:38 21 between 10 to 15 years to develop the composite fan blade
02:53:43 22 for the GE -- first GE9 engine.

02:53:47 23 **Q.** And so how long is a cycle now? When you are developing
02:53:52 24 a new engine, based on your experience that you've gained from
02:53:57 25 these prior engines, how long is it taking?

KRAY - DIRECT (Glatfelter)

20

02:53:59 1 A. I would say we've taken it down from 10 to 15 years to
02:54:03 2 probably 6 to 10 years. Again, it's a learning curve,
02:54:10 3 right. So as you learn things from previous designs -- what
02:54:13 4 works, what doesn't work, design know-how, so to speak --
02:54:17 5 you can shorten that design cycle.

02:54:19 6 And certainly that's one of our goals, right, is to
02:54:21 7 make it as short as possible so we can get a product to our
02:54:24 8 customers faster, and a more reliable product.

02:54:28 9 Q. And you mentioned some specific models of GE engines over
02:54:33 10 time that use the composite blade technology. Can you go
02:54:36 11 through that list again?

02:54:36 12 A. Sure. So the first, first one was certified was the
02:54:40 13 GE94B. All right. And that was on the 777, the first 777
02:54:46 14 aircraft that was launched by Boeing. And that was in circa
02:54:50 15 1995-ish.

02:54:53 16 Okay. The next one after that was the GE90-115B, which
02:54:57 17 goes on the 777, extended ER. They call it the extended
02:55:05 18 range 777 which is basically a bigger 777.

02:55:07 19 And then the GEnx-1B -- which I believe this picture's
02:55:13 20 a GEnx-1B -- that goes on the 787 aircraft. I believe that
02:55:17 21 was certified in -- I think in 2005-ish. Don't quote me on
02:55:26 22 that, but it's around 2005.

02:55:28 23 And then the GEnx-1 -- 2B followed very closely
02:55:32 24 thereafter because we had a request from Boeing to the aging
02:55:36 25 747s. So we basically leveraged this GEnx-1B design to a

KRAY - DIRECT (Glatfelter)

21

02:55:43 1 GENx-2B, a little bit different thrust, different air
02:55:45 2 pumping to match that airframe. That was certified a year
02:55:47 3 or two after the 1B.

02:55:49 4 And then just recently the 9X, which is our latest
02:55:52 5 offering, which is, again, a 13-foot diameter engine, which
02:55:56 6 is going to go on the 777X, which again is an even bigger
02:56:03 7 variant than the 777 from Boeing. But it, again, is not
02:56:05 8 certified yet, with Boeing, but the engine hasn't had all
02:56:08 9 the certification.

02:56:10 10 Q. Now, Mr. Kray, you mentioned several models of GE
02:56:15 11 engines. Are you familiar with the LEAP engines?

02:56:17 12 A. The LEAPs?

02:56:18 13 Q. Yes.

02:56:18 14 A. Yes, I am.

02:56:19 15 Q. What is that?

02:56:19 16 A. The LEAP engine is an engine from our CFM, CFM-I. It's
02:56:26 17 a partnership between GE and our revenue-sharing partner
02:56:30 18 Safran, from France.

02:56:34 19 Q. Okay. And what kind of -- what kind of aircraft is the
02:56:37 20 LEAP engine?

02:56:40 21 A. So the LEAP goes on -- there is basically three main
02:56:43 22 aircraft that the LEAP goes on. It goes on the 737 Max
02:56:48 23 aircraft. This is the one that was recently grounded,
02:56:51 24 right, for all the other issues. It wasn't the engine. But
02:56:53 25 the 737 Max. The 8320, it goes on that; and the COMAC,

KRAY - DIRECT (Glatfelter)

22

02:57:01 1 C919, I think it is.

02:57:06 2 **Q.** And the LEAP engine, does it have composite fan blades?

02:57:10 3 **A.** Yes, it does.

02:57:16 4 **Q.** Have you been involved in the -- in that project?

02:57:21 5 **A.** Yes. So the fan blade is actually owned by our
02:57:24 6 revenue-sharing partner, Safran, from France. However, we
02:57:28 7 were very instrumental in assisting them in getting them
02:57:31 8 that product certified, leveraging our learnings off of our
02:57:36 9 composite fan blades.

02:57:37 10 **Q.** And so what does GE bring to the table in that
02:57:41 11 partnership?

02:57:41 12 **A.** So certainly our expertise in design; our, obviously,
02:57:46 13 design understanding, the material property understanding;
02:57:50 14 our testing methods, which are sometimes unique for
02:57:52 15 composite blades versus a metallic blade; and then our
02:57:57 16 certification approach, which is somewhat unique sometimes
02:58:01 17 with composite versus metallic blades. And all that
02:58:05 18 interaction with how to approach the FAA on the best way to
02:58:08 19 satisfy their requirements for safety of that engine.

02:58:14 20 **Q.** Okay. And what does Safran bring to the table with that
02:58:17 21 particular engine?

02:58:18 22 **A.** So certainly Safran is -- again, they are also an
02:58:21 23 engine company in France. They make more engines than just
02:58:24 24 the CFM, our LEAPs. They make other military and commercial
02:58:29 25 engines. So certainly they have expertise in aerodynamics

KRAY - DIRECT (Glatfelter)

23

02:58:34 1 and just like GE would. They have their own suite of
02:58:37 2 engineering with respect to engine development.

02:58:40 3 Q. So both companies bring their own expertise --

02:58:42 4 A. Yes.

02:58:43 5 Q. -- to --

02:58:44 6 A. It's typically what we call our revenue-sharing
02:58:48 7 partnership, where we both come to the table equally, both
02:58:51 8 from a business perspective, from a monetary perspective,
02:58:57 9 but from a knowledge base to come up with a very viable
02:59:00 10 product.

02:59:00 11 Q. Okay.

02:59:00 12 A. CFM has been -- has been a good partnership since like
02:59:04 13 1980s with GE and Safran and has been very, very -- very,
02:59:10 14 very positive for both companies. We sell a lot of engines.
02:59:15 15 I think all 737s -- well, not all -- I would say the
02:59:19 16 majority of them have either CFM or Flash LEAP engines,
02:59:25 17 which are under the same partnership.

02:59:26 18 Q. Now, you said that GE and Safran have been in sort of a
02:59:32 19 business relationship for back -- back until the '90s or '80s,
02:59:37 20 did you say?

02:59:38 21 A. Probably since the '80s, I believe.

02:59:41 22 Q. Okay. And do they have a composite fan blade apart from
02:59:45 23 the LEAP engine?

02:59:46 24 A. No. LEAP is the only composite fan blade they have.

02:59:51 25 Q. Okay. And so even though you've been working in this

KRAY - DIRECT (Glatfelter)

24

02:59:54 1 joint venture, they haven't been able to develop their own
02:59:57 2 composite fan blade engine?

02:59:58 3 **A.** Well, it's kind of a shared -- it's a little bit of
03:00:05 4 both. Typically, we'd keep our, we keep all of our IP, our
03:00:11 5 intellectual property, separate, whether it's CFM-I or GE or
03:00:15 6 Safran, right. So there's -- there's a very fine line of
03:00:19 7 sharing technology and making an engine versus sharing
03:00:27 8 technology for the sake of sharing technology.

03:00:30 9 **Q.** All right. So for an example, does Safran have access to
03:00:34 10 GE Aviation design files about the composite fan blades used
03:00:37 11 on the GE9X?

03:00:38 12 **A.** No, they would not.

03:00:46 13 **Q.** Do you -- strike that. Because you have this
03:00:48 14 partnership -- because GE Aviation has this partnership with
03:00:52 15 Safran on the LEAP engine, do they have access to other
03:00:58 16 non-public information by GE, other things besides the LEAP
03:01:01 17 engine?

03:01:02 18 **A.** I would say nonpublic, probably yes. I mean, there are
03:01:09 19 a lot of things that we have to share to make an engine
03:01:11 20 work, you know, whether it's interfaces at critical joints.
03:01:15 21 We have to give loads that they can then design their
03:01:18 22 hardware with.

03:01:19 23 So, yeah, I would say they do have some non-public
03:01:22 24 information, certainly.

03:01:23 25 **Q.** Okay. But they don't have like the design files and the

KRAY - DIRECT (Glatfelter)

25

03:01:26 1 testing files and all of the --

03:01:28 2 A. No.

03:01:28 3 Q. -- files you built up over the last 20 to 30 --

03:01:32 4 A. No.

03:01:33 5 Q. -- years?

03:01:33 6 A. Not at all.

03:01:35 7 Q. Has developing these composite fan blades and containment
03:01:39 8 systems been expensive for GE Aviation?

03:01:41 9 A. Yeah. So let's talk about that a little bit. So as I
03:01:47 10 said, if it's a new product, it takes about 10 years to
03:01:51 11 develop a product.

03:01:51 12 And you think about it's kind of built like a learning
03:01:55 13 pyramid, okay? The very bottom is, is you start with the
03:01:59 14 material system composite, for example. And you do coupon
03:02:03 15 testing. You very simple coupon test, and you start to
03:02:07 16 characterize the material itself, you know: How strong is
03:02:10 17 it? When does it break? How does it break? How many times
03:02:14 18 can I bend back and forth, this paper clip, before it starts
03:02:18 19 to fatigue? That's a very basic coupon level.

03:02:21 20 Then I go up to a subcomponent level. I start to look
03:02:26 21 at different features, you know: Can I drill a hole in it?
03:02:29 22 Can I bond metal onto it? You know, how do I protect it
03:02:34 23 from sunlight, ultraviolet lightings, that type of thing.

03:02:40 24 Then I get into component testing. I make a blade. I
03:02:43 25 can test that blade very -- you know, by itself. I can test

KRAY - DIRECT (Glatfelter)

26

03:02:47 1 it either -- and I can shake it, you know, to put vibration
03:02:49 2 into it. I can throw birds at it. I can -- I can pull it
03:02:53 3 until it breaks. That's at the component level.

03:02:57 4 And then certainly as I start getting to, you know,
03:03:00 5 system-level evaluations, I look at disks and spinning it
03:03:06 6 and containment cases and how does it fracture, how does it
03:03:10 7 release. And then at the end, obviously, you have a top-
03:03:13 8 level engine test.

03:03:14 9 So typically that, that type pyramid, to develop that
03:03:19 10 type of pyramid is hundreds of millions of dollars.
03:03:24 11 Astronomical. I mean, a single-engine test for this type of
03:03:30 12 test, just to do a fan blade-out test, which is a very high
03:03:33 13 level on this pyramid, is probably \$15 million. Because the
03:03:37 14 engine alone at the development stage is probably at least
03:03:42 15 \$10 million. And when I do a fan blade-out test, I
03:03:44 16 essentially destroy that engine.

03:03:46 17 So that's the one test, and I have got a whole gamut of
03:03:49 18 tests I have to do to understand the material and certify
03:03:52 19 the material. So it's very, very expensive.

03:03:54 20 **Q.** How much did you say that one test is?

03:03:56 21 **A.** This test is probably at least \$15 million. At least.

03:04:01 22 **Q.** Per test?

03:04:05 23 **A.** For one, for one engine test. Now, I talk about

03:04:07 24 subcomponent tests, you know, a single-blade test. Let's
03:04:12 25 back it down even -- down the pyramid even further, all

KRAY - DIRECT (Glatfelter)

27

03:04:12 1 right?

03:04:16 2 A single-blade test, if I want to, for example, shoot a
03:04:19 3 bird at it, which is -- we can talk about that more -- but I
03:04:24 4 can shoot a bird at it, and that single test is about a
03:04:26 5 quarter million dollars, about \$250,000.

03:04:29 6 So -- and I don't just do one test, right. I have to
03:04:33 7 do a whole gamut of tests to understand what's my threshold.
03:04:36 8 You know, is this spot in the blade critical? Is this spot
03:04:41 9 critical? Is the back? Is the front? So that's -- you
03:04:44 10 know, you could see how it adds up very quickly.

03:04:47 11 **Q.** So I want to ask you about a few things you mentioned
03:04:49 12 there. I will ask about the bird test, but I want to get
03:04:53 13 back. I want to ask the other ones first.

03:04:54 14 You mentioned a fan blade-out test. Is that what you are
03:04:58 15 referring to as testing the engine to failure?

03:05:01 16 **A.** Yes.

03:05:01 17 **Q.** Can you please describe that more to the jury?

03:05:05 18 **A.** Sure. So can I erase this screen some how?

03:05:09 19 THE COURT: We can erase it.

03:05:13 20 THE WITNESS: Perfect. So imagine this is a
03:05:13 21 development engine here, all right? And I have to release the
03:05:18 22 blade there (indicating). That's a requirement from the FAA
03:05:21 23 to say, you have to demonstrate -- GE, you have to demonstrate
03:05:24 24 that if a fan blade fails there, that -- a couple things.
03:05:29 25 Number one, it's contained, right? It doesn't come out of the

KRAY - DIRECT (Glatfelter)

28

03:05:32 1 encasement, hit the aircraft, and go into the passengers,
03:05:36 2 number one.

03:05:37 3 Number two, the engine doesn't fall off of this mount
03:05:42 4 switch up here and this mount here (indicating). The loads,
03:05:46 5 the unbalance of the engine, if I release this big, heavy
03:05:50 6 blade, right, that spins at, you know, 3,000 RPM, as soon as I
03:05:54 7 lose one of those, there is a big imbalance in the engine and
03:06:00 8 it shakes violently. If you ever see one of these tests, I
03:06:02 9 mean, it shakes.

03:06:03 10 So all of the loads going into these structures here are
03:06:06 11 very, very high. We design for them, but you have to prove
03:06:09 12 that our design works. So we test for it. So that's the
03:06:12 13 second thing.

03:06:13 14 And the third thing is anything back in here (indicating)
03:06:15 15 can't start on fire. You can't have a fire in the aircraft
03:06:18 16 because -- or on the engine, right. So even if it holds on
03:06:22 17 the wing, if it's on fire, you know, and you are sitting in
03:06:24 18 the seat and you are looking out the window and see a fire,
03:06:27 19 you're not going to be very happy. So we have to make sure
03:06:30 20 there's not a fire.

03:06:31 21 So those three things, basically, that test damages,
03:06:35 22 completely damages the engine. It's no longer usable for any
03:06:38 23 other test. So that's -- again, a development engine, on this
03:06:42 24 size, is at least \$15 million. At least.

03:06:45 25 BY MS. GLATFELTER:

KRAY - DIRECT (Glatfelter)

29

03:06:45 1 Q. So when you say fan blade-out or test to failure, you
03:06:48 2 mean you have to actually make that engine show how it
03:06:51 3 works --

03:06:52 4 A. Yes.

03:06:52 5 Q. -- when it fails?

03:06:53 6 A. Yes. You have to actually -- what we do on this line
03:06:56 7 down here, this guy down here (indicating), we intentionally
03:06:59 8 put explosives in there and we release it. Spin the engine
03:07:02 9 up to top speed, hit the explosives, it cuts the blade. The
03:07:09 10 blade releases. Has to be shown that it's contained in this
03:07:10 11 structure, right. And then all the subsequent loads and the
03:07:15 12 lack of fire have to be demonstrated.

03:07:17 13 Q. Okay. I'm sure the jury's interested in this because you
03:07:22 14 mentioned a bird test. So before we move on, could you just
03:07:25 15 tell us what you meant by a bird test?

03:07:31 16 A. Sure. So aircraft, you know, when we fly in the air,
03:07:33 17 right, one of the biggest threats for the fan module is,
03:07:36 18 this front end of the engine, is birds. It happens a lot.
03:07:40 19 Bird strikes happen on aircraft all the time.

03:07:43 20 In the Hudson River, right, took a bunch of birds to
03:07:46 21 make the engine stop.

03:07:47 22 So we have to design for bird strike. And one of the
03:07:51 23 things about bird strike is obviously this front profile,
03:07:55 24 the engine, is the first thing the bird's going to hit. So
03:07:58 25 the blades, we have to make sure the blades don't get

KRAY - DIRECT (Glatfelter)

30

03:08:01 1 damaged beyond what -- there is various criteria. The FAA
03:08:07 2 has, based on engine size, criteria for small birds up to
03:08:13 3 two and a half pounds, medium birds up to five and a half
03:08:18 4 pounds, and then very large birds up to eight pounds, a
03:08:21 5 Canadian geese type of bird. You have to show --
03:08:23 6 demonstrate for each one of those bird sizes that your
03:08:26 7 engine, again, is safe; whether it's going to keep producing
03:08:30 8 thrust for small birds -- in other words, if I take off and
03:08:32 9 I take a bird or two, I'll make sure I can keep pushing
03:08:37 10 thrust, right, so I can either turn around to the airport
03:08:40 11 and re-land and I don't have issue; or if it's a very large
03:08:44 12 bird, again, if it breaks a blade off somewhere, that
03:08:48 13 safe -- that engine is still -- contains the piece of blade
03:08:52 14 that's broken off and have safe shutdown. So I can still
03:08:57 15 operate on one engine if I have to and still make a safe
03:09:00 16 return to the airport.

03:09:01 17 So, yeah, birds -- and we have to demonstrate that we
03:09:05 18 have to actually fire birds into an engine to show that that
03:09:09 19 is indeed compliant with those requirements.

03:09:13 20 **Q.** That's an FAA requirement?

03:09:15 21 **A.** It is an FAA requirement. But, again, just like --
03:09:19 22 just like FBO -- we talked about FBO and the cost of doing
03:09:22 23 that -- you know, we don't -- from a business perspective,
03:09:25 24 we don't wait until last minute to do those type of tests.

03:09:31 25 There's a lot of engineering tests that are done before

KRAY - DIRECT (Glatfelter)

31

03:09:34 1 we do our certification test, right. So we do a lot of
03:09:39 2 ingestion on an engineering basis, shoot birds into the fan
03:09:42 3 to make sure that we're comfortable from a design
03:09:46 4 perspective that that design is adequate.

03:09:47 5 And then, certainly, the last test or the certification
03:09:50 6 test is witnessed by the FAA, and that is basically the --
03:09:55 7 you get a checkmark there and say, yeah, you passed that
03:09:58 8 test.

03:09:59 9 But, typically, these big tests, these big, expensive
03:10:03 10 tests, we don't -- we don't just do one test at the end. We
03:10:07 11 do a series of engineering tests to lead up to that
03:10:10 12 successful demonstration. We don't want to do it for the
03:10:13 13 first time in front of the FAA, because you don't want to
03:10:16 14 show the regulatory agencies that, you know, you are very
03:10:20 15 cavalier. It's not a proper design approach.

03:10:23 16 **Q.** Mr. Kray, has the cumulative knowledge gained during the
03:10:27 17 testing and analysis process over these cycles been important
03:10:30 18 to GE Aviation in developing its fan blades and containment
03:10:34 19 system technology?

03:10:35 20 **A.** Well, certainly. And I think the perfect example of
03:10:40 21 that is, as I said, the first composite blade, you know,
03:10:44 22 took probably 15 years to certify. Now that we're up that
03:10:50 23 learning curve, we are down to probably seven, just half
03:10:50 24 that. Or maybe a little bit less than that.

03:10:55 25 So we can leverage off of our current learnings that we

KRAY - DIRECT (Glatfelter)

32

03:11:00 1 document our design practices into our design study
03:11:04 2 summaries that, again, a new engineer can go in, access
03:11:07 3 those studies, and learn what worked and what didn't work so
03:11:12 4 you don't have to reinvent the wheel each time you come up
03:11:16 5 with a new design.

03:11:18 6 **Q.** The results of these composite fan blade testing, it
03:11:22 7 builds on one another, from cycle to cycle?

03:11:26 8 **A.** Yes, as much as we can certainly. Certainly, every
03:11:28 9 engine has its own thrust requirements. So the 9X has a
03:11:33 10 thrush requirement, let's say, of 115,000 pounds of thrust.
03:11:38 11 Where the GEnx might be 70,000 pounds of thrust. So
03:11:43 12 certainly the size of the engine, the RPM, is different for
03:11:46 13 every application to optimally match the engine to the
03:11:50 14 airframe. But certainly, the basic understanding of
03:11:54 15 leverage of that learning curve, yes.

03:11:57 16 In our design reviews, we typically pull up previous
03:12:01 17 designs, how we benchmark against those designs, and say,
03:12:05 18 yeah, you're within that learning curve. If you're not or
03:12:09 19 if you want to deviate from that learning curve, there is
03:12:13 20 certainly a lot more rigor that we would then put on that
03:12:16 21 design to make sure that, again, we have, number one,
03:12:18 22 safety, right, a safe product, first of all. And then,
03:12:21 23 second of all, is it feasible to do that or should you back
03:12:24 24 off your design maybe and get it maybe a little more
03:12:27 25 conservative.

KRAY - DIRECT (Glatfelter)

33

03:12:28 1 Q. And those design files that you were just mentioning,
03:12:31 2 does GE share their design files with its competitors?

03:12:34 3 A. No, not at all.

03:12:38 4 Q. And during these cycles, does GE develop information
03:12:42 5 about the composite fan blades and containment system that it
03:12:46 6 tries to keep secret?

03:12:47 7 A. Yes. A composite fan blade and containment system is
03:12:53 8 what we call our key technology. So it's an internal --
03:12:57 9 internal specification that we at GE Aviation put on. It's
03:13:01 10 one of our -- we consider it our competitive advantage
03:13:07 11 technologies. It is deemed a key technology, which we have
03:13:12 12 a key technology board, which is run by chief engineer's
03:13:17 13 office. And it looks at general technologies across the
03:13:22 14 engine -- certainly composite blades and cases is one of
03:13:24 15 those -- and deems, if it is considered key technology, it
03:13:30 16 puts an additional level of, I am going to call it, security
03:13:32 17 on that information such that it doesn't get disseminated.

03:13:37 18 Q. And would public information -- I'm sorry -- would public
03:13:40 19 disclosure of this information about composite fan blades and
03:13:44 20 composite containment systems that we just talked about, would
03:13:47 21 that disclosure be economically harmful to GE Aviation?

03:13:53 22 A. Certainly, certainly. First of all, it's our
03:13:55 23 composite -- it's our competitive advantage, right. So we
03:13:59 24 know the competitors are trying to get composite fan blades.
03:14:03 25 We know Rolls-Royce, for example, has tried this a couple of

KRAY - DIRECT (Glatfelter)

34

03:14:07 1 times. And I go back to probably 1980 was the first attempt
03:14:12 2 that Rolls-Royce did it. The second attempt was maybe five
03:14:16 3 or ten years afterward. And it almost bankrupt the company
03:14:19 4 because they had put a couple programs mainstream that they
03:14:24 5 were going to use composite blades, and they couldn't make
03:14:26 6 it work. So it was very difficult for them.

03:14:30 7 So certainly, it is our competitive advantage. It's
03:14:33 8 one of the things our customers like about the GE engines,
03:14:36 9 because, again, its durability. You know, its resistance to
03:14:40 10 fatigue. It doesn't come with all the stress risers that
03:14:45 11 have metal blades. It's something that our customers, the
03:14:48 12 airlines, love, is the composite blade.

03:14:53 13 MS. GLATFELTER: All right. I would like to show
03:14:57 14 the witness what's been admitted as Exhibit 69 and publish
03:15:01 15 this to the jury?

03:15:02 16 THE COURT: Yes, show everybody 69.

03:15:10 17 MS. GLATFELTER: Ms. Prim, if we'd pull up the last
03:15:12 18 page of that exhibit. And if you can enlarge it just a little
03:15:20 19 bit.

03:15:23 20 BY MS. GLATFELTER:

03:15:23 21 Q. Now, Mr. Kray, have you seen this document before?

03:15:26 22 A. Yeah.

03:15:30 23 Q. Have you seen this before your testimony today?

03:15:34 24 A. Yes.

03:15:34 25 Q. Okay. And you've had an opportunity to read it?

KRAY - DIRECT (Glatfelter)

35

03:15:35 1 A. Yes.

03:15:36 2 Q. Are there terms on this page that relate to either jet
03:15:46 3 engine composite fan blade or composite fan encasement?

03:15:49 4 A. Certainly. So I hope my pointer will work again. I've
03:15:55 5 got fan rotor blades made of composite materials, okay.
03:15:59 6 That certainly points to GE Aviation. We're the only ones
03:16:04 7 with it, right.

03:16:05 8 Prepreg. Let's talk a little bit about prepreg.
03:16:09 9 Prepreg is composite material. Composite material comes in
03:16:11 10 a couple different forms. Again, it's a fiber and a resin.
03:16:15 11 A prepreg is a combination of those that are basically like
03:16:19 12 a sheet of paper. It's got fibers and it's got resin in it,
03:16:22 13 but it's not cured yet. So prepreg is the composite
03:16:26 14 material itself.

03:16:28 15 So it's asking how many generations of prepreg. So
03:16:30 16 that's a good question. Okay, you know, as I said, this
03:16:33 17 pyramid of learning, the lower pyramid is when we look at
03:16:37 18 all the coupons.

03:16:38 19 And certainly there is a multitude of composite
03:16:41 20 materials out in the industry. It's which one is the right
03:16:43 21 one to use. And that bottom pyramid that you do a lot of
03:16:47 22 component testing on it -- coupon testing helps us sort out
03:16:50 23 which one is right and which one is wrong, and why is one
03:16:54 24 right and one wrong. You know, there's no free lunches,
03:16:57 25 right. So as soon as you find something optimal, it's going

KRAY - DIRECT (Glatfelter)

36

03:17:00 1 to have a down side to it. So it's all the pros and cons of
03:17:05 2 the different materials that can possibly be used in the jet
03:17:09 3 engine, okay.

03:17:12 4 Q. Do you see other terms that relate to composite fan
03:17:15 5 blades or --

03:17:15 6 A. Sure.

03:17:16 7 Q. -- fan blade containment systems?

03:17:18 8 A. Certainly. Fan blade, you know, fan casing here,
03:17:23 9 right. I mean, that, again, composite fan blades, composite
03:17:24 10 materials, right.

03:17:25 11 And, again, now that we are asking here for baseline
03:17:30 12 value is used in the design A or B. Again, what's your down
03:17:34 13 select. What's your criteria for down select. That's very
03:17:37 14 important to short-circuit all that development. We talked
03:17:41 15 about 10 to 15 years. Can I short-circuit that. Can I
03:17:44 16 learn, you know, from other people what's good and what's
03:17:46 17 bad. That certainly is big.

03:17:49 18 Software programs, you know, and virtual simulation,
03:17:55 19 that's one of our big things, right. I mean, we don't -- we
03:17:59 20 certainly test, but we also build mathematical models to
03:18:03 21 break those tests. And to build those mathematical models,
03:18:06 22 to build that correlation of which models work, which ones
03:18:10 23 don't work, how do I correlate to a test result using that
03:18:13 24 simulation. Very, very important to short-cycle that design
03:18:17 25 cycle, okay.

KRAY - DIRECT (Glatfelter)

37

03:18:18 1 3-D braided structure. Again, that's another form of
03:18:22 2 composite. That's one of our forms in our fan containment
03:18:25 3 cases. That certainly is pointing towards that.

03:18:30 4 And then, you know, plus or minus 30 degrees. Now you
03:18:34 5 are talking about specifics of construction. Again, fibers
03:18:37 6 and resin, right. You know, you wrap your -- you wrap your
03:18:41 7 cast around your arm, right, and if it's all one direction,
03:18:44 8 that's great.

03:18:45 9 But the key thing about composites is orientation of
03:18:48 10 fibers, right. So fiber -- fiber direction is very, very
03:18:52 11 strong. But transverse, the other direction, it's just
03:18:56 12 resin, right. So plaster of paris, I can break it, right.

03:19:00 13 So how I orient the fibers to optimize my load is kind
03:19:04 14 of critical in composites. The orientation of the fibers,
03:19:07 15 how you manufacture it, how you orientate the fibers to
03:19:12 16 maximize, again, my strength to make the lightest design.
03:19:15 17 That's key.

03:19:16 18 **Q.** Could discussion of the terms that you've highlighted
03:19:18 19 here, could discussion of these terms lead to discussion about
03:19:23 20 information that GE tries to keep secret about composite fan
03:19:27 21 blades and containment systems?

03:19:29 22 **A.** I would say that the discussions behind these would be,
03:19:32 23 yes, be considered to be proprietary, and we would not -- we
03:19:38 24 would not share that.

03:19:43 25 MS. GLATFELTER: If we could show the witness what's

KRAY - DIRECT (Glatfelter)

38

03:19:44 1 been admitted as Exhibit 6e.

03:19:51 2 And, again, if we look at the last page of Exhibit 6e.

03:19:54 3 And publish that to the jury?

03:19:56 4 THE COURT: Yes, 6e.

03:19:58 5 MS. GLATFELTER: Thank you. One moment.

03:20:05 6 THE WITNESS: This doesn't look like --

03:20:08 7 MS. GLATFELTER: One moment, Your Honor.

03:20:10 8 THE COURT: Yes.

03:20:13 9 MS. GLATFELTER: Actually, I'm not sure we need to
03:20:15 10 take a break or not, but I want to make sure I find the right
03:20:19 11 exhibit.

03:20:19 12 THE COURT: I am prepared to take a break if it
03:20:22 13 would be convenient.

03:20:22 14 MS. GLATFELTER: Yes. Thank you, Your Honor.

03:20:24 15 THE COURT: We will take a 20-minute break. During
03:20:25 16 the break, take the break. Don't discuss the case among
03:20:28 17 yourselves or with anyone else. No independent research.
03:20:31 18 Continue to keep an open mind.

03:20:32 19 Out of respect for you, we'll rise as you leave.

03:20:35 20 THE COURTROOM DEPUTY: All rise for the jury.

03:20:38 21 (Jury out at 3:20 p.m.)

03:21:11 22 THE COURT: The jury has left the room. We're going
03:21:14 23 to break 20 minutes, till 3:41.

03:21:19 24 During the break, sir, do not discuss your testimony,
03:21:22 25 please.

KRAY - DIRECT (Glatfelter)

39

03:21:23 1 We're in break until that time. When we come back, we
03:21:27 2 will proceed. I'm going to need to stop abruptly by 4:25. We
03:21:39 3 are in recess for 20 minutes.

03:21:39 4 THE COURTROOM DEPUTY: The court is now in recess.

03:21:42 5 (Recess from 3:21 p.m. until 3:39 p.m.)

03:39:27 6 THE COURT: We're back in the courtroom. Is there
03:39:31 7 anything that requires my attention before we get the jury,
03:39:35 8 from the government?

03:39:35 9 MS. GLATFELTER: No, Your Honor.

03:39:35 10 THE COURT: From the defense?

03:39:40 11 MR. McBRIDE: No, sir.

03:39:42 12 THE COURT: Forgive me. Are we now at
03:39:44 13 cross-examination?

03:39:45 14 MS. GLATFELTER: No. I still have some more
03:39:47 15 questions to go.

03:39:47 16 THE COURT: Very well. Let's call for the jury,
03:39:50 17 please.

03:39:56 18 And the witness can retake the stand and be seated.

03:41:14 19 THE COURTROOM DEPUTY: All rise for the jury.

03:41:16 20 (Jury in at 3:41 p.m.)

03:41:46 21 THE COURT: You may all be seated. Thank you.

03:41:51 22 All 15 jurors are back. Thank you for your attention.
03:41:56 23 We will continue to hear government questions of this witness.

03:41:59 24 You may proceed, counsel.

03:42:01 25 MS. GLATFELTER: Thank you.

KRAY - DIRECT (Glatfelter)

40

03:42:03 1 Before the break, I had asked if the witness could be
03:42:06 2 shown Exhibit 6e, and published to the jury because it's
03:42:09 3 admitted.

03:42:10 4 THE COURT: 6e, we'll show it to everyone.

03:42:16 5 MS. GLATFELTER: Thank you. We're looking at the
03:42:17 6 last page -- or the second page. Sorry.

03:42:17 7 BY MS. GLATFELTER:

03:42:25 8 Q. Mr. Kray, do you see that on your screen?

03:42:26 9 A. Yes, I do.

03:42:27 10 Q. And I want to go through the same exercise we did before.
03:42:32 11 We're looking at this document. If you can tell us whether
03:42:35 12 any of these terms relate to composite fan blade or composite
03:42:44 13 containment system technology.

03:42:46 14 A. Certainly. So certainly we have obviously casing here,
03:42:53 15 right. We are talking about materials, structure, and
03:42:56 16 strength, right.

03:42:57 17 Q. Mr. Kray, I am going to ask you to pull the microphone
03:43:00 18 closer to you so we can hear you while you are looking at the
03:43:02 19 screen.

03:43:02 20 Okay. Thank you.

03:43:03 21 A. So we have materials, structure, and strength, right.
03:43:07 22 So, again, how we manufacture that blade and how we design
03:43:11 23 it to optimize the strength, okay, is key.

03:43:15 24 Manufacturing. How you make the blade, right. So how
03:43:20 25 you -- again, the fibers, how you assemble the fibers,

KRAY - DIRECT (Glatfelter)

41

03:43:24 1 orientations, et cetera, are all in that manufacturing.

03:43:32 2 This right here, design flow, ideas, principles, this
03:43:37 3 guy right here (indicating), that's the whole process of,
03:43:41 4 you know, how you actually go through the design process,
03:43:44 5 how you -- what's your design principles, and how do you
03:43:50 6 know one design's good and one is not.

03:43:53 7 And then demonstration, validation steps. We talked
03:43:57 8 about the testing, right. That's all built into that
03:44:00 9 validation.

03:44:00 10 Manufacturing, certainly that's -- that's key.
03:44:04 11 Manufacturing of these products is, you know, you can design
03:44:07 12 them, but if you can't make them, you're not going to have
03:44:10 13 very good product, right. So it's all a balance of what can
03:44:14 14 you manufacture. Can you manufacture it reliably every
03:44:20 15 time, makes it a viable product.

03:44:22 16 And then implement it in engineering down here. The
03:44:27 17 drawings, certainly that is very proprietary data. The
03:44:31 18 drawing basically defines your design. The drawing is
03:44:34 19 essentially engineering's communication with manufacturing.
03:44:40 20 I can take a drawing, a physical drawing and give it to the
03:44:43 21 manufacturer and they can make that part. So the drawing
03:44:45 22 has a lot of information on it about the product.

03:44:49 23 And then experimental tests and process standards.
03:44:53 24 Again, all that learning that we go through, that 10 or 15
03:44:58 25 years of process steps: You know, how do you -- how do you

KRAY - DIRECT (Glatfelter)

42

03:45:01 1 experimentally test it, how do you design a test such that
03:45:06 2 you can maximize your knowledge of that material system is
03:45:09 3 key.

03:45:09 4 **Q.** All right. And if we look at the top of the document,
03:45:13 5 and there are some terms there, are any of those terms
03:45:17 6 specific to composite fan blade?

03:45:19 7 **A.** Certainly. Material and size, right. That certainly
03:45:23 8 is key, right. I mean, what's the size of your blade. You
03:45:27 9 know, how big can you make it. What your thickness is.

03:45:31 10 Again, all of these not only play in performance from a
03:45:35 11 pumping air perspective but also from a credibility
03:45:42 12 perspective.

03:45:43 13 I think I know an aero guy, an aero design engineer
03:45:46 14 wants the air flow to be as thin as this sheet of paper, but
03:45:48 15 we know it's not going to survive, right. The first time it
03:45:52 16 hits a rock or a bird, it's going to break. So it's that
03:45:55 17 balance of size and definition of what works and what
03:45:59 18 doesn't work.

03:45:59 19 **Q.** And we see down in the middle of the page "A, B,
03:46:05 20 reference, value, and confidential."

03:46:07 21 When you were describing the modeling and the software
03:46:09 22 that you use before you go into actual component testing,
03:46:12 23 could these terms relate to that?

03:46:17 24 **A.** Well, I don't know what it really means by A and B. It
03:46:20 25 looks like it's some type of comparison. I don't know if

KRAY - DIRECT (Glatfelter)

43

03:46:24 1 it's been redacted out of here.

03:46:25 2 But, certainly, again, it's a trail on material
03:46:27 3 systems, first of all, the material perspective, but also
03:46:31 4 the analytical perspective. We talked about building
03:46:35 5 analytical models to match testing, right. You like to do
03:46:38 6 tests, but you also like to do analytical predictions so you
03:46:43 7 can analytically iterate on design features and save
03:46:47 8 yourself some testing. Certainly, you'll test at the end,
03:46:49 9 but the more you can analytically understand the material
03:46:53 10 system, the geometry of the blades or cases, the better off
03:46:58 11 you are from a, you know, design cycle timing-wise. So if I
03:47:04 12 understand it more mathematically, I can do simulations to a
03:47:08 13 certain point. And then at some point I test. And either I
03:47:10 14 validate those simulations or I go back and modify my
03:47:14 15 simulations to say, I learned something new. I need to
03:47:17 16 modify my understanding.

03:47:20 17 **Q.** Thank you. Now, these are general terms up on the screen
03:47:25 18 that you've highlighted, right?

03:47:26 19 **A.** Yes.

03:47:27 20 **Q.** Could discussion of these terms by someone with knowledge
03:47:32 21 of GE Aviation's composite fan blade and composite containment
03:47:38 22 system lead to a discussion of secret GE information about
03:47:42 23 those topics?

03:47:43 24 MR. McBRIDE: Objection. Calls for speculation.

03:47:47 25 THE COURT: Overruled.

KRAY - DIRECT (Glatfelter)

44

03:47:48 1 You can answer the question. Do you need it again?

03:47:53 2 THE WITNESS: So the data behind this, yes, would be
03:47:56 3 very proprietary for all the, you know, things we have
03:48:00 4 highlighted here. That supporting data for those statements
03:48:05 5 is certainly the meat of the proprietary nature of the
03:48:09 6 composite blades and cases.

03:48:11 7 BY MS. GLATFELTER:

03:48:13 8 Q. Do you know someone by the name of David Zheng?

03:48:19 9 A. You mean Daihu?

03:48:21 10 Q. Daihu Zheng?

03:48:23 11 A. Yes, I know -- I actually knew him very well.

03:48:25 12 Q. Did you work together?

03:48:27 13 A. Yes.

03:48:29 14 Q. And on what?

03:48:30 15 A. So I first met Daihu when he worked at our Global
03:48:35 16 Research Center in Niskayuna, New York. He was a research
03:48:41 17 engineer there. He supported -- you know, we talked about
03:48:43 18 the lineage of composite fan blades on GEnx fan blades. He
03:48:52 19 was supporting that analysis of those test predictions.

03:48:55 20 And then Daihu eventually moved to Evendale and
03:48:59 21 supported the GE9X program, which is our latest composite
03:49:07 22 fan blade case program, again doing analytical predictions
03:49:10 23 and manufacturing integration of those products.

03:49:11 24 Q. And as someone working on those projects, did Mr. Zheng
03:49:15 25 have access to design data, testing files, and other

KRAY - DIRECT (Glatfelter)

45

03:49:19 1 information that GE Aviation tries to keep secret?

03:49:22 2 **A.** Yes, he would, as being a part of those programs.

03:49:27 3 **Q.** Aside from those files themselves, would an engineer --
03:49:31 4 would he know public information -- I'm sorry. Let me strike
03:49:35 5 that.

03:49:36 6 Aside from the files, would he know non-public
03:49:39 7 information about GE fan blades and containment system
03:49:42 8 technology that GE would not want shared with outsiders?

03:49:45 9 **A.** Yes, he would. Again, we talk about the building block
03:49:48 10 approach, right. We're taking one design and leveraging it
03:49:55 11 to another design, et cetera. He would obviously be
03:49:59 12 integral with that, to help design the new designs.

03:50:02 13 **Q.** Mr. Kray, a few last questions about steps GE takes to
03:50:06 14 protect information. Now, as an engineer, do you work on a GE
03:50:10 15 campus?

03:50:10 16 **A.** Yes, I do.

03:50:12 17 **Q.** And can you briefly describe what kind of physical
03:50:17 18 security measures, if any, exist around the areas where you
03:50:20 19 work?

03:50:21 20 **A.** So certainly there is card access to any building on
03:50:27 21 GE -- in GE campus. Whether it's an off-site building or
03:50:31 22 the main campus, you have card access. There is additional
03:50:36 23 access. If you're in a, let's say, more secured area, you
03:50:41 24 have a card and another pass code to get into the door.
03:50:46 25 Certainly that's -- that's the first level of security from

KRAY - DIRECT (Glatfelter)

46

03:50:49 1 the access perspective, physical.

03:50:51 2 Q. And as an engineer at GE Aviation, have you been issued a
03:50:55 3 laptop?

03:50:55 4 A. Yes, I have.

03:50:56 5 Q. Okay. And could you briefly describe some of the
03:50:59 6 security measures surrounding that laptop?

03:51:02 7 A. Could you repeat the question?

03:51:03 8 Q. Sure. Do you have a GE Aviation laptop?

03:51:06 9 A. Yes, I do.

03:51:07 10 Q. Okay. And are there -- is there security around that
03:51:10 11 laptop, for example, in the way that you log on or access
03:51:14 12 files?

03:51:14 13 A. Yeah. We use what we call a two-factor, or two-factor
03:51:19 14 authentication. The first one is you have your user ID,
03:51:24 15 which is a code, and then you have a password associated
03:51:28 16 with that. Okay, that's the first level.

03:51:30 17 The second level then they've gone to this chip where
03:51:34 18 you have to insert a personal chip that you are -- that you
03:51:39 19 are given to access that computer.

03:51:43 20 Q. Okay. Are there security measures in what kind of design
03:51:47 21 files and testing data about composite fan blades in terms of
03:51:53 22 accessing the data?

03:51:54 23 A. So as far as our design practices and what I call
03:52:01 24 design practices, which is, for example, when you -- when
03:52:04 25 you do, for example, let's say the fan blade-out test,

KRAY - DIRECT (Glatfelter)

47

03:52:07 1 right. There'll be documentation of that. There will be
03:52:10 2 analytical predictions of that.

03:52:12 3 We typically take that data, even in its entire or
03:52:16 4 separate sections, and record it into what we call our
03:52:20 5 design record books. This is electronic system internal in
03:52:24 6 GE, which is a named access only. So to get access to those
03:52:28 7 you have to again go through the password and key access to
03:52:34 8 get electronic access to them. And then even the -- since
03:52:40 9 composite blade is considered key technology, it's also
03:52:43 10 named access. In other words, if I make design practice
03:52:47 11 summary of a test, as owner of that design summary I would
03:52:52 12 personally give access to person X, Y, or Z on a
03:52:57 13 need-to-know basis.

03:52:59 14 **Q.** All right. And as an engineer working on the composite
03:53:02 15 fan blade, if you wanted to present information about that
03:53:04 16 subject, let's say, to -- publicly at a conference, what, if
03:53:09 17 any, steps would you have to take at GE Aviation to do so?

03:53:12 18 **A.** Okay. So there's actually -- there's two steps you
03:53:16 19 have to go through. We have what we call design boards,
03:53:20 20 which are -- which are focused boards of folks, technical
03:53:27 21 experts, that are specific to a discipline.

03:53:30 22 For example, my design board is polymeric composites.
03:53:39 23 That's a design board. There is a design board for
03:53:42 24 turbines, turbo air flow, or dynamics, et cetera.

03:53:45 25 So your first step is to take your presentation draft

KRAY - DIRECT (Glatfelter)

48

03:53:48 1 to the design board. That would be reviewed then with the
03:53:52 2 technical experts for release of information. You know, is
03:53:57 3 it something we'd want to release to the public. Okay,
03:54:01 4 that's the first step.

03:54:02 5 Once it goes through that iteration and say, yeah, the
03:54:05 6 design board feels that the technical concept is acceptable
03:54:11 7 to distribute, that package then goes to legal, and legal
03:54:15 8 has a review of that information that also says from a legal
03:54:18 9 perspective it's okay to present.

03:54:20 10 **Q.** And those are the steps that you're trained to go through
03:54:23 11 if you wanted to discuss this technology outside of GE
03:54:28 12 Aviation?

03:54:28 13 **A.** Yeah. Whether it's -- whether it's for advertisement
03:54:32 14 purposes or if somebody wants to go to a symposium and
03:54:36 15 present a paper, the same way.

03:54:40 16 MS. GLATFELTER: Just one moment, Your Honor.

03:54:55 17 (Pause.)

03:54:55 18 BY MS. GLATFELTER:

03:54:57 19 **Q.** When we were looking at 6e before, Mr. Kray, I forgot to
03:55:02 20 have you scroll down and look at the rest of the exhibit. And
03:55:06 21 I just wanted to do that before we end it.

03:55:08 22 We were looking at Exhibit 6e. As a reminder, whether
03:55:14 23 there were any types of words or terms on there about the
03:55:18 24 composite fan blade technology.

03:55:22 25 MS. GLATFELTER: And if we scroll down to the bottom

KRAY - DIRECT (Glatfelter)

49

03:55:24 1 of that page, Ms. Prim.

03:55:24 2 BY MS. GLATFELTER:

03:55:32 3 **Q.** So I think we went through all the numbers except 3 or 4.

03:55:39 4 **A.** Yeah, so certainly -- certainly, materials, right. I
03:55:41 5 mean, material was used and how -- you know what material
03:55:43 6 are you using in your designs.

03:55:46 7 Production processes. Again, that's the manufacturing
03:55:48 8 method, right. How do you work with the material.

03:55:52 9 Material brands, you know, this is, we buy our material
03:55:56 10 from -- we don't make our own composite material. We'll buy
03:56:01 11 it. It's commercially available. So what brand names are
03:56:04 12 you using, right.

03:56:07 13 Standards. You know, all of our material we have
03:56:11 14 specifications and standards. You know, if you go to buy,
03:56:16 15 let's say, anything from a manufacturer, they are going to
03:56:21 16 have their advertisement of how great their material is,
03:56:23 17 right. Certainly, we take that with a grain of salt. We
03:56:26 18 don't really believe it. I mean, we actually do our own
03:56:30 19 testing to say, yeah, it's right or maybe it's not really
03:56:33 20 exactly right. It's a good advertisement article, but it's
03:56:37 21 not -- for our needs it's not adequate.

03:56:41 22 So what we typically do is once we understand a
03:56:43 23 material, we write our own specifications and our own
03:56:47 24 standards to say if we are going to ship me that material to
03:56:49 25 make a composite fan blade, you have to meet these

KRAY - DIRECT (Glatfelter)

50

03:56:52 1 specifications or I'm not going to accept the material,
03:56:54 2 because I know that my assumptions for strength and
03:56:57 3 durability rely on these specifications of material.

03:57:02 4 Performance parameters. Certainly, how well -- how
03:57:06 5 well does the material perform. Not only from a strength
03:57:08 6 perspective but the fan blade from a -- from an overall
03:57:12 7 pumping air, right. The main thing is the fan blade is
03:57:16 8 going to pump air. And that's its whole purpose in life is
03:57:19 9 to pump air. If it does pump air very well, and how does it
03:57:24 10 deflect the load. Those are all reason for performance.
03:57:26 11 Again, highest performing engine is what we're trying to
03:57:30 12 achieve.

03:57:32 13 And then, obviously, test data. You know we talked
03:57:34 14 about test data, right. That's very important.

03:57:36 15 **Q.** And before when we stopped, when we ended our discussion
03:57:41 16 of this exhibit, I had asked you do discussion of these terms,
03:57:43 17 discussion of these new terms lead to discussion of GE's
03:57:47 18 secret information about composite fan blades and containment
03:57:51 19 systems?

03:57:51 20 **A.** Certainly. All the material behind those terms is, is
03:57:56 21 what we're trying to protect.

03:57:58 22 **Q.** For example, the specifications that you were mentioning
03:58:00 23 before, is that one of the things that GE doesn't share with
03:58:04 24 the public or competitors?

03:58:05 25 **A.** We do not share with our competitors. We share with

03:58:08 1 our suppliers, right. When we buy material, we say you have
03:58:13 2 to meet this specification, and they obviously -- obviously
03:58:18 3 have witness to that.

03:58:18 4 Q. And the test data is another example?

03:58:21 5 A. Yes.

03:58:22 6 Q. Thank you.

03:58:22 7 MS. GLATFELTER: No further questions.

03:58:28 8 THE COURT: The lawyer for the defendant has an
03:58:31 9 opportunity to ask questions of you at this time.

03:58:34 10 Cross-examination. We're going to break abruptly at
03:58:40 11 4:25.

03:58:41 12 MR. McBRIDE: Yes, sir.

03:58:42 13 **CROSS-EXAMINATION**

03:58:43 14 BY MR. McBRIDE:

03:58:44 15 Q. Good afternoon, Mr. Kray. How are you today?

03:58:46 16 A. I'm very good. How are you?

03:58:47 17 Q. Good, thank you. My name is Bob McBride, and I am one of
03:58:51 18 the lawyers that represent Mr. Xu today in this case.

03:58:53 19 One of the things that I believe you testified about was
03:58:57 20 it was important to have safe vehicles and safe products for
03:59:02 21 FAA certification, correct?

03:59:04 22 A. Well, that is correct, but not only from a
03:59:08 23 certification perspective but from, you know, the overall
03:59:16 24 design, right. I mean, we can meet certification
03:59:19 25 requirements, but over and above that we want to make sure

KRAY - CROSS (McBride)

52

03:59:24 1 it's safe.

03:59:24 2 Q. Absolutely. Because people's lives are at stake.

03:59:25 3 A. Certainly.

03:59:26 4 Q. Absolutely. And I'm not contesting that in any way,
03:59:30 5 shape, or form.

03:59:33 6 I am going to try to go backwards a little bit here if I
03:59:35 7 could. I believe you testified earlier that in order for a
03:59:39 8 presentation to be made it had to be cleared by a board,
03:59:45 9 correct?

03:59:45 10 A. Correct.

03:59:46 11 Q. And cleared by legal, correct? So there are some
03:59:50 12 instances then when there are presentations made that show GE
03:59:54 13 images, correct?

03:59:55 14 A. That's correct.

03:59:57 15 Q. Are you aware if any of those kinds of presentations
03:59:59 16 include composite -- jet engine with composite fan blades and
04:00:06 17 housings?

04:00:06 18 A. Well, certainly the picture we just looked at, right.
04:00:10 19 I mean, that's a general picture of a composite blade
04:00:13 20 encased. That's certainly a public -- a public figure.

04:00:16 21 Q. And, in fact, let me ask this question. Have you looked
04:00:21 22 at the Safran website regarding the LEAP engine?

04:00:25 23 A. Can you repeat your question?

04:00:27 24 Q. Have you looked at Safran's website -- pardon me -- CFM
04:00:34 25 International's website?

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53

04:00:35 1 A. I may have looked at it once or twice, I'm sure.

04:00:38 2 Q. Seen the images of a LEAP engine there?

04:00:40 3 A. Sure, sure.

04:00:41 4 Q. So the technology itself or the fact that there are

04:00:45 5 composite -- let me rephrase. The fact that there are

04:00:48 6 composite fan blades and containment housings in and of itself

04:00:51 7 is not a secret that GE wants to keep?

04:00:58 8 A. I think the fact that composites are out in industry is

04:01:01 9 something we want to promote because it is our commercial

04:01:05 10 advantage. Now, how to make those certainly is something we

04:01:09 11 want to protect.

04:01:10 12 Q. I understand. But these vehicles -- pardon me. These

04:01:13 13 jet engines are sold all over the world; is that correct?

04:01:15 14 A. That is correct.

04:01:16 15 Q. In fact, it's one of GE's best selling products in terms

04:01:20 16 of jet engines, is it not?

04:01:22 17 A. That is correct.

04:01:24 18 Q. And that's because it is a more durable and lighter jet

04:01:27 19 engine you can build?

04:01:29 20 A. Correct.

04:01:29 21 Q. And that makes it easier to make a larger and lighter

04:01:32 22 aircraft too?

04:01:33 23 A. That's -- that is our goal, yes.

04:01:36 24 Q. Very generally.

04:01:37 25 A. Yes.

04:01:37 1 Q. Obviously, I don't have the technical knowledge.

04:01:43 2 One of the things I believe you just talked about, sir,
04:01:47 3 was buying the materials. You will get specifications from
04:01:51 4 various vendors; is that correct?

04:01:55 5 A. So we -- we get specifications from a supplier of a
04:02:00 6 very general nature. Okay. Now, certainly, they like to
04:02:02 7 sell their product, right, so they'll say how great it is.
04:02:06 8 Again, we -- we take that as a first step.

04:02:11 9 Second step is we go and validate. You know, there is
04:02:14 10 no perfect world, right. So we make sure that what they say
04:02:18 11 is true and house, you know -- if I have a manufacturing
04:02:21 12 material that's balanced on a pin of a head, right, which is
04:02:25 13 sometimes what they'll try to sell --

04:02:27 14 Q. Um-hmm.

04:02:28 15 A. -- as soon as they deviate on their material from one
04:02:30 16 way or the other, it has a big debit. And that's what we
04:02:35 17 try to understand when we put specifications in. If I say
04:02:38 18 that I manufacture our material at, let's say, 200 degrees,
04:02:43 19 for example, I manufacture my prepreg at 200 degrees. If I
04:02:48 20 manufactured it at 205 degrees, are my properties consistent
04:02:54 21 or do they fall off?

04:02:56 22 So, again, understanding that when we call design space
04:02:59 23 around the -- all the products, whether it's material or
04:03:02 24 even the design itself, is critical.

04:03:05 25 Q. So the consistency of the material, particularly the

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55

04:03:07 1 fibers, is important in the ceramic matrix design and
04:03:12 2 manufacturing process, is it not?

04:03:13 3 A. So ceramic matrix is a little different.

04:03:19 4 Q. Metric. Pardon me.

04:03:19 5 A. So we talk about polymeric matrix, right. Ceramic
04:03:23 6 matrix is, again, it's a composite but it's in the back of
04:03:26 7 the engine. It's a very, very high temperature capability.
04:03:30 8 That's not in the fan.

04:03:31 9 The polymeric, which is epoxy-based composites, are
04:03:33 10 what we are dealing with here.

04:03:34 11 Q. My apologies. I meant polymetric composite.

04:03:39 12 But in the design and manufacturing of the polymetric
04:03:44 13 components, it's very important to have a consistent and
04:03:47 14 stable fiber, is it not, that you start with?

04:03:49 15 A. That is correct.

04:03:50 16 Q. And if you were to start the design process with a
04:03:54 17 different fiber, that would impact the entire cycle design,
04:03:59 18 manufacturing process cycle, would it not?

04:04:01 19 A. It would -- you would have to go back and repeat a lot
04:04:05 20 of that characterization to understand that material just as
04:04:09 21 well, yes.

04:04:09 22 Q. And, in fact, it would impact the computer modeling
04:04:12 23 codes --

04:04:12 24 A. Certainly.

04:04:13 25 Q. -- would it not?

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56

04:04:14 1 A. Certainly.

04:04:14 2 Q. So even a change as minor as a fiber can impact the
04:04:18 3 entire design-build process, correct?

04:04:22 4 A. Yes. Whether it's fiber size, fiber direction, even --
04:04:27 5 even the supplier of the fiber. You know, whether I buy it
04:04:31 6 from Company A or Company B, fiber is not always fiber,
04:04:35 7 right. You have to make sure that you understand that
04:04:37 8 potential subtle difference which could make a big
04:04:41 9 difference in design, yes.

04:04:42 10 Q. So were one to hypothetically try to replicate GE's
04:04:46 11 process, they would have to know exactly the fiber you buy and
04:04:53 12 exactly the tests you need and what the tolerances are that
04:04:56 13 you evaluate it at; is that correct?

04:04:59 14 A. I would say that's correct.

04:05:00 15 Q. You spoke, sir, about coupon testing and component
04:05:10 16 testing.

04:05:10 17 A. Um-hmm.

04:05:11 18 Q. What is that general process called?

04:05:14 19 A. Well, again, I don't know if you'd really call it a
04:05:20 20 process. We call it the hierarchy of learning, the pyramid
04:05:24 21 of learning, right. So the very basic level when you're
04:05:27 22 trying to sort out, let's say, again when you talked about
04:05:31 23 fiber size and parameters, right. It's sorting out, you
04:05:35 24 know, material A versus material B verses resin A versus
04:05:40 25 resin B and a combination thereof. All that gets done at

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57

04:05:43 1 the very basic level, which is you can go through a lot of
04:05:48 2 coupons rather quickly versus trying to build the parts and
04:05:52 3 build tooling and test parts, yes, sir.

04:05:55 4 Q. So is this process generally known as the building block
04:05:59 5 process?

04:06:00 6 A. That is correct.

04:06:00 7 Q. And so the building block process is well-known in the
04:06:06 8 industry for making composites, correct?

04:06:09 9 A. That is true, yes.

04:06:10 10 Q. So if I wanted to make a composite flying pig, I may want
04:06:13 11 to use the building block process, correct?

04:06:16 12 A. You can make golf shafts or whatever, sure.

04:06:19 13 Q. So almost anything made of composites will use this
04:06:22 14 building block process; is that fair?

04:06:26 15 A. Typically, that's -- that's the industry standard, yes.

04:06:29 16 Q. And within the building block process, the industry
04:06:32 17 standards that you have mentioned is to start with the coupon
04:06:35 18 test, correct?

04:06:36 19 A. That's correct.

04:06:36 20 Q. And the coupon test -- and correct me if I'm wrong,
04:06:40 21 sir -- is a very tiny bit of material when you begin the
04:06:44 22 testing, correct?

04:06:45 23 A. It is limited in size. The coupons are typically, you
04:06:49 24 know, on the order of an inch by a couple inches. It's
04:06:51 25 rather small material.

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58

04:06:52 1 Q. Relative to the size of the fan blades and --

04:06:54 2 A. Oh, yes.

04:06:55 3 Q. -- the fan case, they are pretty small, aren't they, sir?

04:06:57 4 A. Yes.

04:06:57 5 Q. So -- and the purpose of this is you will take a coupon

04:07:00 6 with the fibers and the epoxy and you will test it for its

04:07:04 7 performance, correct?

04:07:05 8 A. Correct.

04:07:06 9 Q. And that performance is in terms of stretching the

04:07:11 10 material, correct?

04:07:12 11 A. It's -- it's stretching. It's twisting. You know, you

04:07:17 12 build up internal shears. It's fatigue. Again, the paper

04:07:22 13 clip, how many times can I bend it back and forth before it

04:07:25 14 breaks. All that -- all that type of basic, I am going to

04:07:29 15 call it basic testing, yes.

04:07:30 16 Q. So just for point of reference, the shear that you

04:07:33 17 mentioned, sir, is shearing of the layers of the coupon; is

04:07:37 18 that correct?

04:07:37 19 A. That's correct.

04:07:38 20 Q. And then as I understand the process -- and my view is

04:07:42 21 very simple -- you will then put components together, coupons

04:07:46 22 together, and test larger pieces of the coupon test?

04:07:51 23 A. Yeah. You'll -- you'll go from a coupon testing up to

04:07:55 24 basically then you might have some specific feature testing,

04:07:58 25 right.

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59

04:07:58 1 So let's talk about composite fan blade, for example.

04:08:02 2 The retention system, how I hold it in a disk. I may test

04:08:06 3 only that feature in a -- in a static type of pole test just

04:08:11 4 to understand how those shears and capabilities work

04:08:14 5 together when I go from a coupon level to a more complex,

04:08:21 6 multi -- multilayer or composite construction that might be

04:08:27 7 similar to the architecture of my proposed design.

04:08:31 8 Q. So you are basically going from the bottom up, and you

04:08:31 9 have --

04:08:31 10 A. Right.

04:08:34 11 Q. And you have a -- you have coupons large enough, and then

04:08:36 12 at some point you are going to want to get to do some more

04:08:40 13 sophisticated testing, correct?

04:08:41 14 A. Correct.

04:08:41 15 Q. So, for instance, you were mentioning a more complex

04:08:45 16 geometric shape that you might want to test, like a bend in a

04:08:51 17 blade, correct, sir?

04:08:51 18 A. Correct.

04:08:52 19 Q. Is that fair?

04:08:53 20 A. Sure.

04:08:53 21 Q. And there are also other tests that you do. You, like,

04:08:56 22 punch a whole in a block of coupons and test how that reacts

04:09:00 23 when you pull it, correct?

04:09:01 24 A. Yeah. Damage -- we typically call that damaged

04:09:05 25 tolerance. We will intentionally put damage in the material

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60

04:09:08 1 and see how it reacts. Again, you know, safety, right. If

04:09:11 2 I --

04:09:11 3 **Q.** Sure.

04:09:12 4 **A.** -- pick up a rock off the runway, it hits a composite
04:09:16 5 part, does damage. The aircraft's in the air. Is it going
04:09:19 6 to propagate and cause more damage? I want to know that
04:09:23 7 ahead of time.

04:09:23 8 **Q.** Absolutely. So each piece that you test, you essentially
04:09:27 9 test it to destruction of that coupon or component, correct?

04:09:30 10 **A.** Typically to destruction, yeah. We want to know the
04:09:34 11 thresholds. Certainly, what I'm going to call the elastic
04:09:38 12 portion. You know, how much it bends and deforms under --
04:09:42 13 just on the elastic load.

04:09:44 14 And then ultimate load. How it breaks. What is the
04:09:47 15 failure mode. Does it -- does it split apart or do the
04:09:52 16 fibers break.

04:09:53 17 All that understanding is critical to take it to the
04:09:56 18 next level of actual component design.

04:09:59 19 **Q.** And as I understand it, with the results of this
04:10:03 20 destructive test, whichever type it is, you will then do a
04:10:06 21 modeling, a computer modeling for the next?

04:10:09 22 **A.** That's right. That's correct. We try to -- we try to
04:10:13 23 build these computer models, simulations, to again capture
04:10:18 24 that capability because, again, if we can use that
04:10:23 25 understanding to drive the design at the next level higher,

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61

04:10:28 1 which is the blade level or the case level, that certainly
04:10:32 2 will help us, you know, shorten that design cycle and get a
04:10:36 3 little bit of learning, yes.

04:10:38 4 Q. And the program -- correct me if I'm wrong about this --
04:10:42 5 that GE generally uses is LS Dyna, correct?

04:10:45 6 A. That's correct. That is a commercial code. It's
04:10:48 7 available across the board. But it's like -- it's a very,
04:10:52 8 I'm going to call it, open architectural program.

04:10:54 9 Q. Um-hmm.

04:10:57 10 A. So you need to put in your material, I'm going to call
04:11:01 11 it material models, your material understanding. And let's
04:11:05 12 say a typical composite material model may have 15 or 20
04:11:13 13 constants to have to be put into that computer language so
04:11:16 14 it understands how it breaks under tension, compression,
04:11:19 15 shear, all right. And all those constants are derived off a
04:11:24 16 coupon testing.

04:11:25 17 Q. Sure.

04:11:26 18 A. And feeds into the overall material model.

04:11:30 19 So, yeah, Dyna is a very generic code. It's very --
04:11:34 20 you don't buy it with composite material properties in it,
04:11:38 21 right. You have got to put those in yourself.

04:11:40 22 Q. Understood. But there are other similar programs out
04:11:43 23 there that are commercially available?

04:11:45 24 A. Oh, sure. There is Abacus, there is Dytran, there is
04:11:49 25 Dyna. You know, again, it's user preference. We have

04:11:52 1 built -- basically over the last probably 15, 20 years
04:11:57 2 maybe, Dyna has been our choice of software. We've used
04:12:02 3 others before that, but it looks likes Dyna is becoming the
04:12:05 4 industry standard.

04:12:06 5 **Q.** So within the modeling process and the computer model
04:12:14 6 generation, that's all based on what I will call trial-and-
04:12:17 7 error testing that you have done in the past?

04:12:20 8 **A.** Yeah. So as I might have mentioned earlier, that
04:12:26 9 builds your basic understanding, builds your constants for
04:12:30 10 materials.

04:12:31 11 Now, as you get into, let's say -- let's take it to the
04:12:34 12 next level up. A bird ingestion, for example. I use that
04:12:38 13 model, that computer simulation code to predict what might
04:12:41 14 happen when a bird hits --

04:12:42 15 **Q.** Right.

04:12:42 16 **A.** -- the airfoil. I predict it. I adjust my
04:12:48 17 thicknesses. I kind of optimize my design to make it work.
04:12:51 18 At least on the computer it works. And then I do a test.
04:12:56 19 And the test may come back and say, yes, your prediction is
04:12:59 20 good. So you go to the next level. If it's not good, I
04:13:03 21 need to go back and understand why and adjust my material
04:13:08 22 assumptions or my material model of why it didn't work
04:13:11 23 because I certainly need to understand that to make my
04:13:23 24 efficient design.

04:13:24 25 **Q.** Let me follow on with -- and I think this is what you're

KRAY - CROSS (McBride)

63

04:13:27 1 saying, sir -- is that to a certain degree building a
04:13:29 2 polymetric composite component part is dependent on the
04:13:35 3 in-house processes?

04:13:36 4 A. I would say it's built on the learnings, yes. Again,
04:13:41 5 you are leveraging a building block. And in our case, since
04:13:44 6 we are on, what I will call, almost our fifth generation of
04:13:48 7 composite families, is building upon the hierarchy of those
04:13:52 8 generations.

04:13:52 9 Q. So let me run down a list of things that I want to ask
04:13:55 10 you if they're significant.

04:13:57 11 A. Um-hmm.

04:13:57 12 Q. So I think you've already talked about a knowledge base
04:14:00 13 regarding your design; is that correct?

04:14:02 14 A. Could you repeat that again?

04:14:04 15 Q. So the company's knowledge base --

04:14:05 16 A. Yes.

04:14:05 17 Q. -- and the design --

04:14:05 18 A. Yes.

04:14:07 19 Q. -- is an important thing, and that's all in-house,
04:14:09 20 correct?

04:14:09 21 A. Yes.

04:14:09 22 Q. And then the preferences regarding the modeling codes we
04:14:12 23 just talked about, correct?

04:14:14 24 A. Correct.

04:14:15 25 Q. Something that GE develops over time, correct?

04:14:20 1 And then the in-house guidelines you might have for the
04:14:24 2 product itself, correct?

04:14:25 3 A. Yeah. And we talk in-house guidelines, it's, okay,
04:14:28 4 what kind of stress levels can I live with for either
04:14:31 5 fatigue, right, my bending, my -- you know, go back to my
04:14:35 6 paper clip. You know, how much, how much bending can I do
04:14:38 7 to make sure it fatigues right. All that is kind of built
04:14:41 8 into that learning.

04:14:43 9 Q. Right. And then the manufacturing expertise and
04:14:45 10 limitations, that's an important component, correct?

04:14:48 11 A. Certainly manufacturing because, again, if you
04:14:52 12 manufacture on the pin of a head, you need to understand any
04:14:56 13 deviation to that manufacturing so I don't put a product out
04:14:59 14 the door that I assume is this capable and it's only this
04:15:03 15 capable (indicating).

04:15:04 16 Q. I'm not looking at my watch because I am concerned about
04:15:08 17 your testimony. I want to make sure I don't blow the judge's
04:15:11 18 timeline.

04:15:11 19 THE COURT: I'll take care of that.

04:15:13 20 MR. McBRIDE: Thank you.

04:15:15 21 BY MR. McBRIDE:

04:15:22 22 Q. And GE, of course, is a global manufacturer and has --
04:15:23 23 tell me if this is fair -- compared to most of its
04:15:26 24 competitors, huge personnel and financial resources to develop
04:15:31 25 technology, correct?

04:15:31 1 A. Yeah, I would say. You know, when you look at jet
04:15:35 2 engines, right, you've got three main players and maybe a
04:15:38 3 couple smaller players. You've got GE, Pratt & Whitney, and
04:15:44 4 Rolls-Royce are the three main players in the industry.

04:15:47 5 And you have Safran and Honeywell, which I want to call
04:15:50 6 it -- are also players but probably not as big as the top
04:15:55 7 three.

04:15:56 8 Q. So I believe you told us that the building block is a --
04:16:04 9 building block approach is a basic way to building component
04:16:08 10 structures, sir; is that correct?

04:16:09 11 A. The building block understanding, yes.

04:16:11 12 Q. And this is essentially the process that General Electric
04:16:15 13 has -- GE Aviation has used in building its components,
04:16:19 14 polymetric component fan blades and housings, correct?

04:16:24 15 A. I would say yes.

04:16:25 16 Q. And it could -- and other organizations, if they spent
04:16:28 17 the time and the money, could also build polymetric fan blades
04:16:34 18 and housing using the same basic method, correct?

04:16:37 19 A. I would say that is correct, but others have tried and
04:16:42 20 not succeeded.

04:16:46 21 Q. Well, you mentioned Rolls-Royce. I believe in the '80s,
04:16:50 22 sir, it almost went bankrupt. Is that what you said?

04:16:52 23 A. Yes.

04:16:53 24 Q. In the '80s, I think you would agree with me that
04:16:56 25 computer capabilities were not quite what they are today.

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66

04:17:00 1 A. I would a hundred percent agree.

04:17:05 2 Q. And so that certainly might have been a factor in the

04:17:07 3 problems that Rolls-Royce had in creating the --

04:17:11 4 A. Yes, that is true, but our competitors still don't have

04:17:16 5 composite blades. And the funny thing is they have metallic

04:17:21 6 blades and they paint them to look like composite blades.

04:17:24 7 Q. So you are telling me that Rolls-Royce UltraFan's engines

04:17:28 8 do not have composite fan blades?

04:17:30 9 A. They are touting that it does, but it is not certified.

04:17:33 10 Q. Well, that doesn't mean it is not a composite fan blade,

04:17:36 11 though, does it?

04:17:37 12 A. It can look good on a shelf, but it doesn't fly yet.

04:17:41 13 Q. That doesn't mean it's not a composite fan blade, does

04:17:44 14 it, sir?

04:17:45 15 A. It's a composite fan blade.

04:17:47 16 Q. All right. Would you agree with me also that it takes a

04:17:52 17 lot of institutional resolve to develop this kind of product?

04:17:57 18 A. I think it takes a lot of dedication, certainly. I

04:18:02 19 mean, we talked 10 to 15 years of development process to do

04:18:06 20 that, and that's with a large team working on it. Not only

04:18:10 21 design but materials, certification, testing. It's -- it's

04:18:18 22 several. I will say a hundred people.

04:18:22 23 Q. But you would agree with me that were another

04:18:25 24 organization to have those skills, likes Rolls-Royce, they

04:18:29 25 could develop composite fan blades and housings?

KRAY - CROSS (McBride)

67

04:18:33 1 A. I guess it's feasible.

04:18:35 2 Q. Thank you, sir. Those are all the questions I have.

04:18:38 3 THE COURT: Very well. Is there redirect of this
04:18:40 4 witness?

04:18:45 5 MS. GLATFELTER: No, Your Honor.

04:18:47 6 THE COURT: Very well. Sir, your testimony is
04:18:50 7 complete and you have appeared to have survived, and you are
04:18:52 8 free to go.

04:18:53 9 THE WITNESS: Thank you, sir.

10 (Proceedings reported but not transcribed.)

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14 _____ 31st of October, 2021

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